U.S. Fish & Wildlife Service

Watts Branch, Washington, D.C. Watershed and Stream Assessment

CBFO-S02-03

WATTS BRANCH, WASHINGTON, D.C.: WATERSHED AND STREAM ASSESSMENT

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U.S. Fish & Wildlife Service
Chesapeake Bay Field Office

CBFO-S02-03

Prepared in cooperation with:

District of Columbia, The Department of Health, Watershed Protection Division

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2002

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I. INTRODUCTION

The District of Columbia, Department of Health (DOH), Watershed Protection Division and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Service) entered into an agreement to conduct an assessment of the Watts Branch watershed, located in the District of Columbia (D.C.) and Prince George's (P.G.) County (Figure 1). The Service conducted a detailed stream assessment for the portion of Watts Branch located within D.C. Specific restoration recommendations are limited to the portion of the stream and watershed located in D.C., with general recommendations for the portion of the watershed in P.G. County. More specific recommendations for the portion of Watts Branch in P.G. County will require additional detailed watershed and stream assessment.

As one of the largest tributaries to the Anacostia River located within D.C. boundaries the restoration of Watts Branch is critical to the restoration of the Anacostia River, a secondary tributary to the Chesapeake Bay. The Anacostia watershed is identified as one of three Areas of Concern by the Chesapeake Bay Program, and is one of most impaired rivers in North America identified by the American Rivers, Inc.

Many government agencies, environmental organizations, and other stakeholders are focusing significant resources toward the protection and restoration of the Anacostia River and its watershed. The Anacostia restoration efforts have received both Congressional and White House recognition (Shepp and Cummins 1997).

The main-stem of Watts Branch is a perennial stream classified by U.S. Geological Survey (USGS), which generally maintains flow year round. The majority of the stream is affected by extensive channelization and floodplain loss. In addition, portions of the stream are impacted by stormwater outfalls and confinement in concrete channels or culverts. Many bank stabilization projects are located along the stream, some of which are undermined and falling into the stream. Failure of these projects is a significant concern as the subsequent bank erosion will deliver a large quantity of sediment into the stream. All the tributaries to Watts Branch have been filled in, enclosed in pipes, or confined in concrete channels, with the exception of 500 linear feet of one tributary in D.C.

Most of the riparian forest associated with the D.C. portion of Watts Branch is designated as a federal park, owned by National Park Service (NPS). The National Wetland Inventory (NWI) map has identified two tidal emergent riverine wetlands and one open water wetland associated with the Anacostia River and the tidal portion of Watts Branch (*i.e.*, Reaches WB-15 and WB-16). The NWI map also identified one riverine, tidal wetland, two riverine, lower perennial wetlands, and several palustrine, emergent and forested wetlands associated with the Watts Branch.

II. PROJECT OBJECTIVES

The project objectives of this watershed and stream assessment are to: 1) characterize physical conditions of the stream, 2) target and prioritize stream reaches and riparian areas for restoration, 3) identify watershed and instream conditions impacting the stream and riparian habitat;

and 4) target and prioritize watershed conditions for restoration. The goal of the stream restoration is to return the stream to a stable, self-maintaining state which maximizes aquatic habitats. Stream stability is a dynamic process with a tendency toward a dynamic equilibrium between the stream's discharge, sediment transport, stream dimension, planform patterns, and longitudinal profile. The Service will use the watershed and stream assessment to develop a stream restoration design for Watts Branch.

The Anacostia Watershed Restoration Committee developed six major restoration goals for the Anacostia watershed: 1) pollutant load reduction, 2) stream protection and restoration, 3) anadromous fish spawning habitat restoration, 4) wetland restoration and creation, 5) forest expansion; and 6) public awareness and involvement (MWCOG 1991). The Watts Branch stream and watershed restoration will directly or indirectly address many of these environmental concerns. A successful stream restoration will also have a broader impact on the Chesapeake Bay and its natural resources.

III. METHODOLOGY

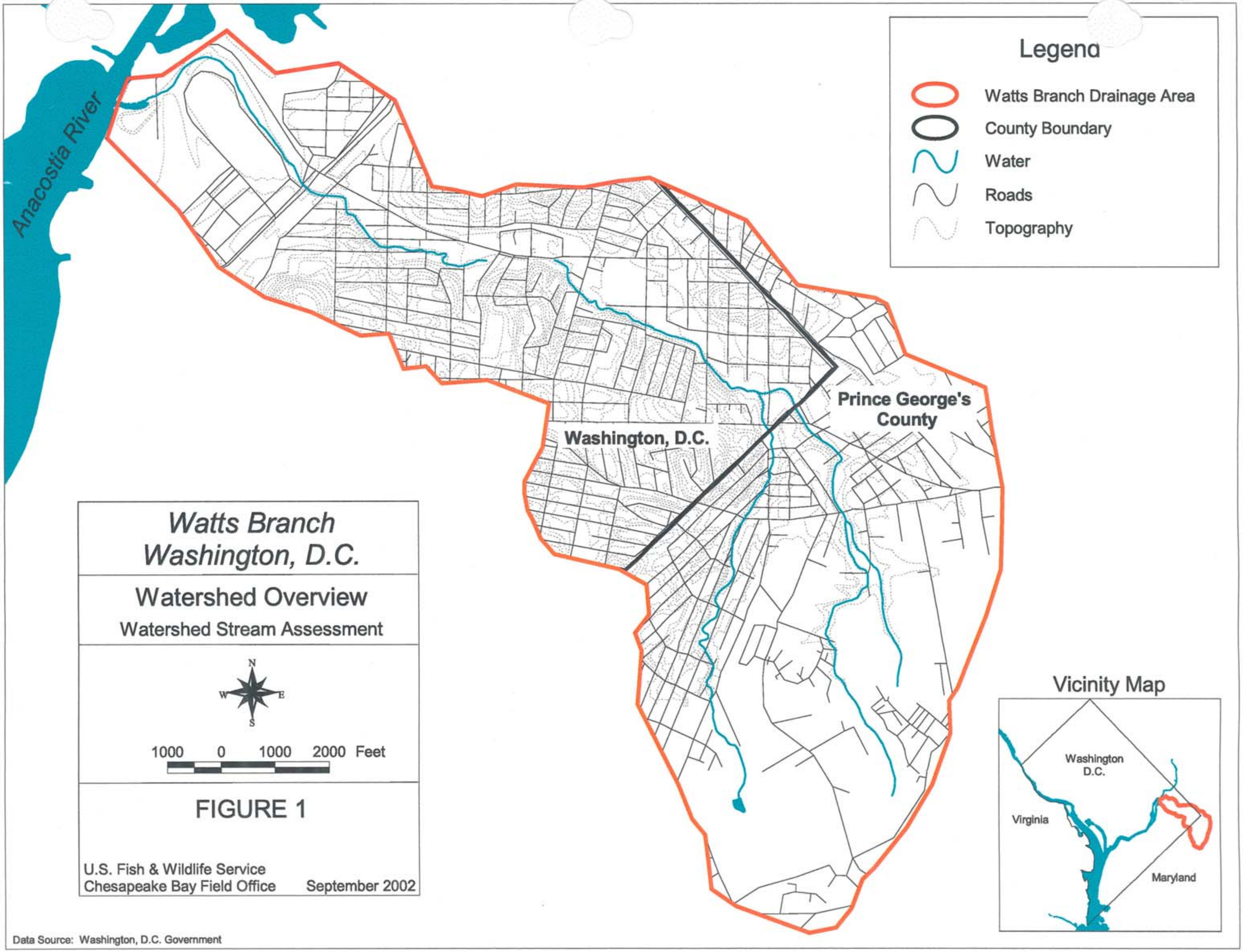
A brief summary of methods used by the Service to assess the watershed and stream condition is presented; however, a more detailed description of the methods used by the Service is described in the Watts Branch Scope of Work. The only change in methodology was the substrate sampling technique. Instead of pebble counts, bulk samples were collected due to a water quality advisory recommending no human contact. Particle distribution was determined by sieving the bulk samples in the laboratory.

A. Watershed Assessment

For the watershed assessment, the Service evaluated historic and existing watershed characteristics (*e.g.*, land use, land cover, soil types, and geology) and identified watershed and stream conditions which may impact Watts Branch. The Service evaluated these factors to provide an understanding of the historic conditions which may have contributed, and the existing conditions which are still contributing to the current stream state. This information allows the Service to identify trends and predict potential future conditions which take into account regional influences.

B. Stream Assessment

For the stream assessment, the Service evaluated the existing geomorphic character and condition of the stream. The Service conducted a Rosgen Level I, II, and III stream assessment. The Rosgen Level I assessment describes the general geomorphic character of the stream and watershed. The Rosgen Level II assessment describes, in detail, the existing morphological character of the stream. The Service also uses this information to classify the stream using the Rosgen Stream Classification System. The Rosgen Level III assessment describes the stability condition of the stream. The typical data collected in all three levels include bankfull dimensions, planform dimensions, floodprone dimensions, geomorphic mapping, bed materials, stream bank and bed stability, longitudinal facet profile, bar sampling, entrainment computations, predicted sediment supply, Pfankuch reach inventory and channel stability evaluation, and stream evolution.



Anacostia River
Legend
Watts Branch Drainage Area
County Boundary
Water
Roads
Topography
Prince George's County
Washington, D.C.
Watts Branch
Washington, D.C.
Watershed Overview
Watershed Stream Assessment
N
W
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1000 0 1000 2000 Feet
FIGURE 1
U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
September 2002
Vicinity Map
Washington D.C.
Virginia
Maryland
Data Source: Washington, D.C. Government

The Service established monuments at representative cross sections. The location of these monuments were documented on the geomorphic maps and their global positioning coordinates were recorded to allow for future surveys to validate stability predictions.

This information is typically compared to a reference stream condition to determine the impaired stream's departure from a reference condition. The Service was unable to find a reference stream reach in the Watts Branch watershed with the appropriate stream type or appropriate length. However, the Service was able to use information gathered from stable cross sections, and dimensionless reference reach data developed by Wildland Hydrology to conduct some of the stability analysis.

All the data collected in Levels I through III assessments is associated with bankfull discharge. Therefore, the Service conducted a gage calibration to examine local relationships between drainage area, bankfull discharge, and stream dimensions. The Service compared the calculated bankfull discharge and dimensions from the detailed surveys on Watts Branch to those conducted at the USGS Watts Branch gage and with regional curves developed by the Service.

C. Problem Identification and Prioritization

The Service used the data from the Level I, II, and III assessments to identify and prioritize problems. The Service ranked the stability conditions of each reach relative to one another and to stable stream conditions. We also analyzed stream characteristics based on management interpretations of various stream types presented in Rosgen (1996). The stream sensitivity analysis evaluated such parameters as sensitivity to disturbance, recovery potential, and sediment supply. Sensitivity to disturbance is a measure of a stream's tolerance to changes in watershed conditions, including sediment output, peak discharge, and response timing. Recovery potential relates to the stream's ability to recover once the cause of disturbance is removed.

The Service used this analysis process to identify site-specific stream stability problems, outfall instability problems, and source runoff problems within the watershed. Additionally, the Service combined all the data collected to develop a reach stability rating and reach restoration prioritization determination, an outfall prioritization determination, and a source runoff control prioritization determination.

IV. EXISTING CONDITIONS

A. Watershed Characterization

1. Historical Overview

The Service was unable to find documentation of early historical watershed conditions and land uses specifically for the Watts Branch watershed. However, a considerable amount of information was available for the Anacostia watershed. Prior to the twentieth century, large portions of the Anacostia watershed were converted from forests and meadows to crop land. Following World War II, the Anacostia watershed developed and grew in population (Shepp and Cummins 1997).

The Service reviewed historical maps and aerial photographs dated 1895, 1927, 1988, and 1995 to determine historic land use trends. The 1895 Coastal and Geodetic Survey map reveals extensive forest clearing in the lower portion of the watershed and the establishment of a few scattered farm and residential houses in the middle and upper portions of the watershed. The map also shows the establishment of the Benning Race Course on the farthest downstream section of the watershed. The 1927 aerial photograph shows urban development occurring first in the lower portions of the watershed and the construction of additional home sites and farms in the remaining portions of the watershed. The Service was unable to obtain aerial photographs or maps from 1926 to 1988, but based on the Anacostia historic data we believe that there was an increase in development of residential, commercial, and industrial land uses from 1945 through the 1970s. The development probably started at the 1927 urban development area and sprawled upstream. By the 1980s, most of the land available for development within the D.C. portion of the watershed was probably urbanized. The 1995 aerial photographs show extensive urbanization, consisting mostly of residential and commercial land with some minimal park land in the D.C. portion of the watershed and moderate to low density residential housing in the P.G. portion of the watershed. Today, most of the development in the D.C. portion of the watershed consists of renovating existing structures or razing existing structures and building new structures. The P.G. portion of the watershed has active new house construction in undeveloped areas of the watershed.

The Service also used the historical maps and aerial photographs for a trend analysis of Watts Branch. Because of the concerns over the accuracy of the historic maps, their scales, resolution, and leaf-on conditions in the aerial photographs, the Service can only generally characterize the historic trends for Watts Branch. The 1895 map shows channelization in some areas, particularly adjacent to Benning Race Course. However, the majority of Watts Branch was a natural meandering stream with numerous tributaries and adjacent wetlands. The 1927 aerials do not show the stream clearly enough for the Service to determine whether other portions of Watts Branch were altered. Based on Service field observations and analyses of field data, essentially 100 percent of the stream in the D.C. portion of the watershed has been channelized or altered. Additionally, a comparison of the 1895 map to today's stream system show a significant loss in stream miles (primarily old tributaries to Watts Branch) and wetlands and a significant increase in drainage density from the numerous stormwater utility lines constructed throughout the watershed. Impacts associated with the loss of stream miles and wetlands is obvious - they no longer exist or provide habitat for wildlife. An increase in drainage density adversely affects the watershed hydrology. The primary impact is the large amount of water reaching the stream system much quicker. A detailed description of impacts associated with the increased drainage density is presented in the Problems Section.

2. Geology and Soils

There are six geologic formations found in the Watts Branch watershed (Figure 2). The geologic formations range from the Pleistocene period to the Upper Cretaceous period. The Patapsco formation is the dominant geologic formation, comprising approximately 47 percent of the watershed. The Service did not identify any geologic conditions which would impact the Watts Branch stream and watershed restoration.

In general, soils found in the Watts Branch watershed are typical of those found in the Mid-Atlantic coastal plain, with the exceptions of the Sanitary Landfill, Urban-Christiana land complex, and Urban-Galestown land complex (Figure 3). The landfill and urban soils comprise approximately 95 percent of the D.C. portion of the Watts Branch watershed. According to the Soil Survey of District of Columbia (1976), approximately 70 percent of these urban soils are significantly covered by impervious surfaces. In addition, many of the soils in D.C. are impacted by soil fill. These disturbances have altered soil permeability, runoff potential, and erosion potential.

During the stream restoration design phase, the Service may recommend soil fertility testing on soils that are characterized as having surface soil fills and/or low fertility, to accurately assess soil conditions prior to riparian restoration. Soil amendments may be required as part of the riparian planting plan. Additional precautions are necessary with soils characterized as having moderate and high erosion potential.

3. Land Use/Land Cover

The Service created a Land Use/Land Cover map from watershed data compiled by D.C. and P.G. County (Figure 4). The land use/land covers are grouped into five general categories: 1) low and medium density residential, 2) deciduous forest, 3) parks and open space, 4) commercial, industrial, and government lands, and 5) waters and wetlands. The low and medium density residential, commercial, industrial, and government land categories comprise 80.5 percent of the watershed (Table 1).

The government land category includes federal and local government buildings, schools, military installations, and churches. The parks and open space categories include most of the riparian forest associated with the portion of Watts Branch located in D.C. The riparian forest associated with this category is designated as federal park owned by NPS, and includes Kenilworth Park, a landfill converted into a recreational park.

From this land use information, the Service determined that approximately 32 percent of the entire watershed, and 36 percent of the D.C. portion of the watershed consists of impervious surface. However, the D.C. portion of the watershed may have a percent imperviousness as high as 70 percent based on soil descriptions provided by the United States Department of Agriculture (USDA 1976). The impervious surfaces consist mostly of low and medium density residential, commercial, and industrial land uses.

Table 1. Watts Branch. Land Use/Land Cover Summary	
Land Use/Land Cover Category	**Percent of Watershed**
Low and Medium Density Residential	73.2
Deciduous Forest	11.0
Parks and Open Space	8.2
Commercial, Industrial, and Government Lands	7.3
Open Water and Wetlands	0.3
Total Percentage	**100.0**

4. Hydrology

The hydrology of Watts Branch is significantly influenced by urbanization. The effects of urbanization on the hydrology of a stream include increases in the amount and rate of stormwater runoff, and the potential for bank and bed erosion resulting in stream enlargement and incision. The increased amount and rate of stormwater runoff are transported to Watts Branch through a large number of stormwater outfalls located throughout the length of the stream. A review of the Sewershed Map created by the Service (Figure 5), revealed no additional flows contributed to the watershed from outside sources.

The USGS, with cooperation from the NPS, is operating an active gage station on Watts Branch, located 200 feet upstream from Minnesota Avenue. The gage station was established in June 1992 and has a drainage area of 3.28 square miles. The average mean annual discharge is 4.48 cubic feet per second (cfs), with the lowest and highest mean annual discharge of 2.84 cfs and 5.87 cfs, respectively. The lowest measured flow is 0.28 cfs and the highest peak flow is 1510 cfs.

5. Riparian Vegetation

The riparian buffer is a critical component of the ecology and stability of a stream. In addition to providing terrestrial habitats for a variety of wildlife, including neotropical migratory songbirds, the riparian buffer protects and enhances the associated aquatic habitat. The riparian buffer provides nutrient and sediment reduction, temperature regulation, and biomass for the stream and aquatic wildlife. The riparian buffer also enhances stream stability by physically stabilizing the stream banks and floodplain.

The Service evaluated the riparian buffer condition as a forested buffer. Where there was no forested buffer, the assessment defined it as a lack of buffer. Approximately 35 percent of Watts Branch in D.C. has no buffer, due primarily to land use practices. Riparian widths range from 0 to 250 feet, with an average width less than 20 feet. However, these widths frequently represent one side of the stream, and it is common to find a narrow or nonexistent buffer along the other bank.

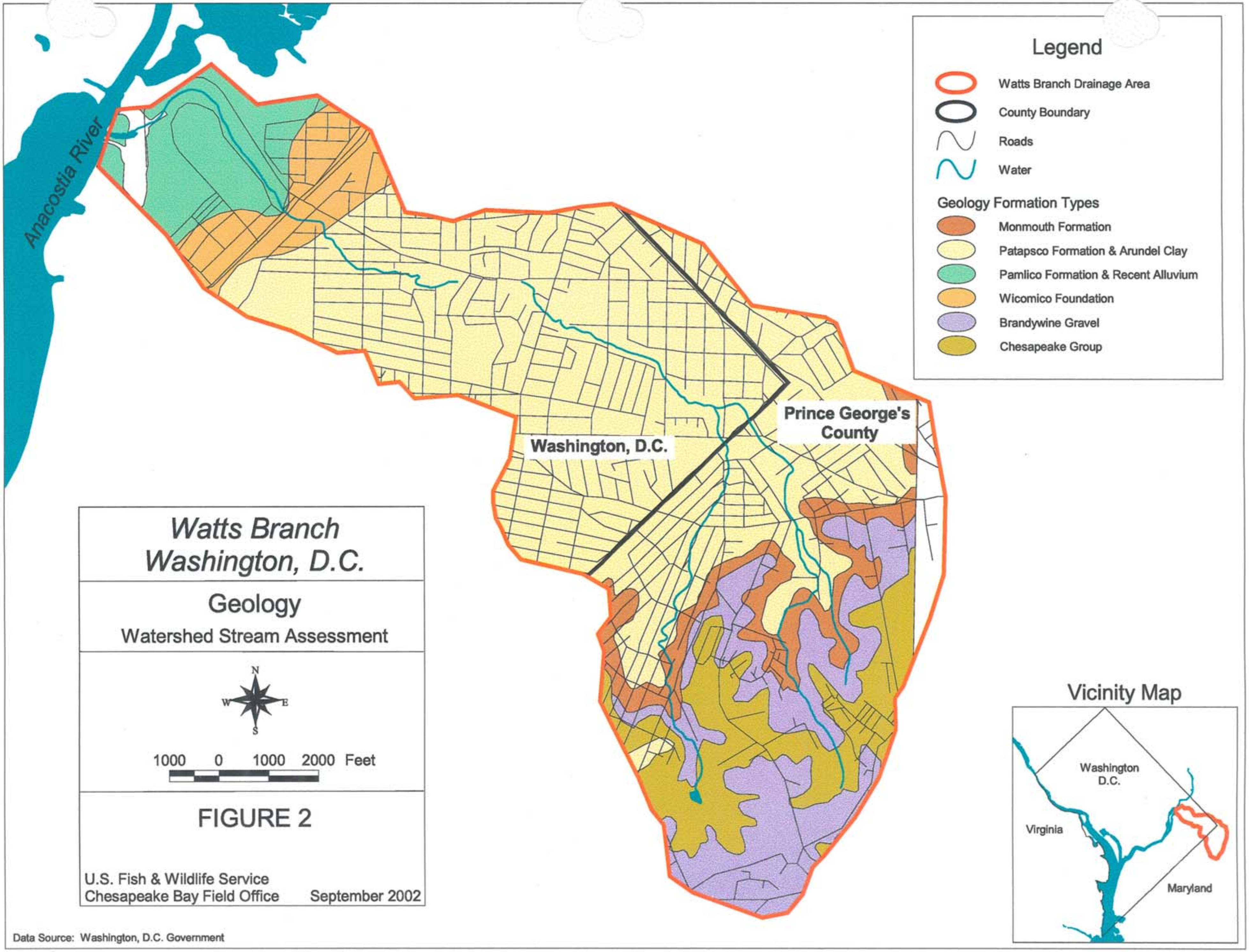
Anacostia River
Washington, D.C.
Prince George's County
Legend
Watts Branch Drainage Area
County Boundary
Roads
Water
Geology Formation Types
Monmouth Formation
Patapsco Formation & Arundel Clay
Pamlico Formation & Recent Alluvium
Wicomico Foundation
Brandywine Gravel
Chesapeake Group
Watts Branch
Washington, D.C.
Geology
Watershed Stream Assessment
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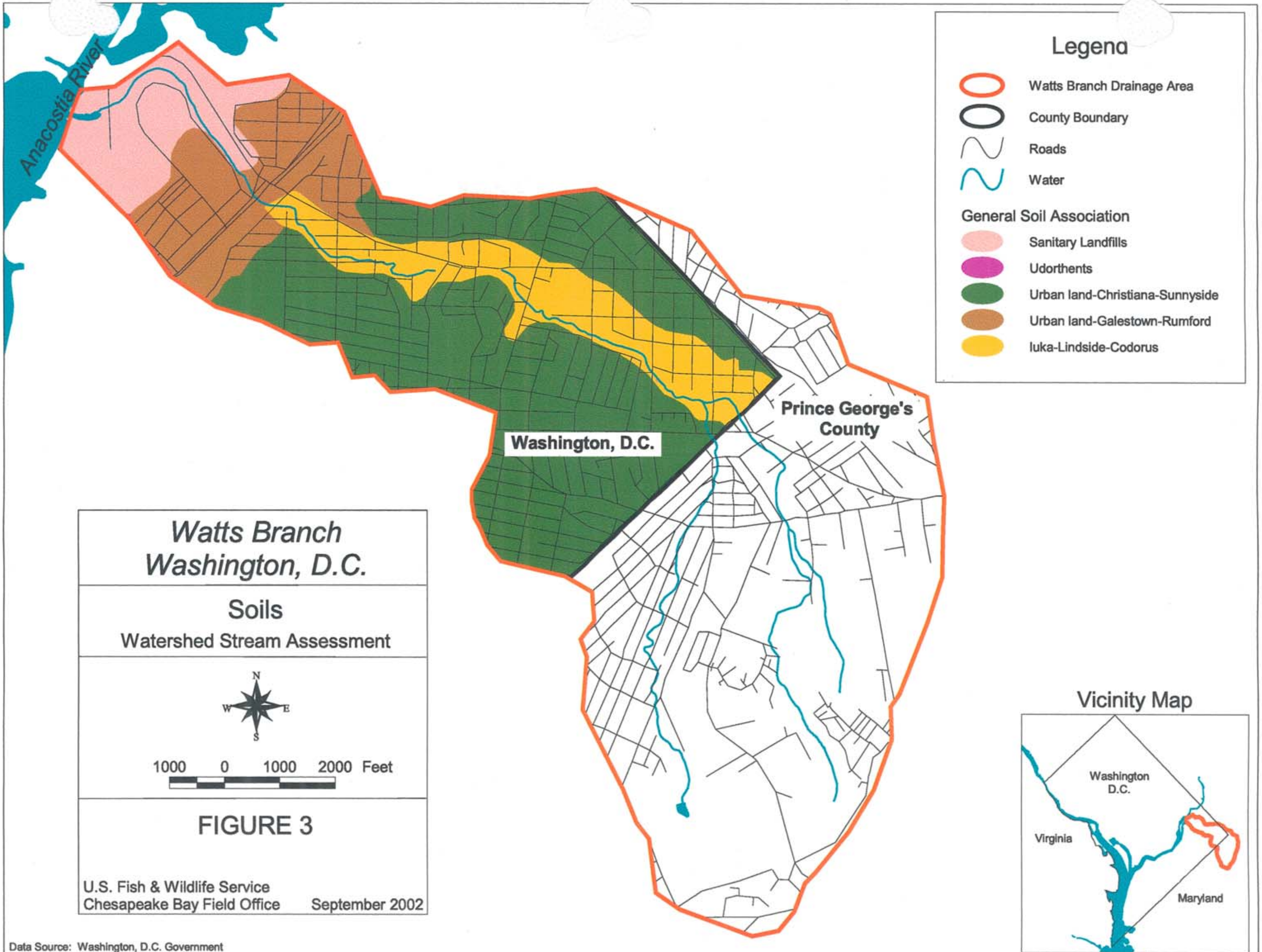
FIGURE 2
U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
September 2002
Vicinity Map
Washington D.C.
Virginia
Maryland
Data Source: Washington, D.C. Government


Legend
Watts Branch Drainage Area
County Boundary
Roads
Water
General Soil Association
Sanitary Landfills
Udorthents
Urban land-Christiana-Sunnyside
Urban land-Galestown-Rumford
Iuka-Lindside-Codorus
Anacostia River
Washington, D.C.
Prince George's County
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Washington D.C.
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Washington, D.C.
Soils
Watershed Stream Assessment
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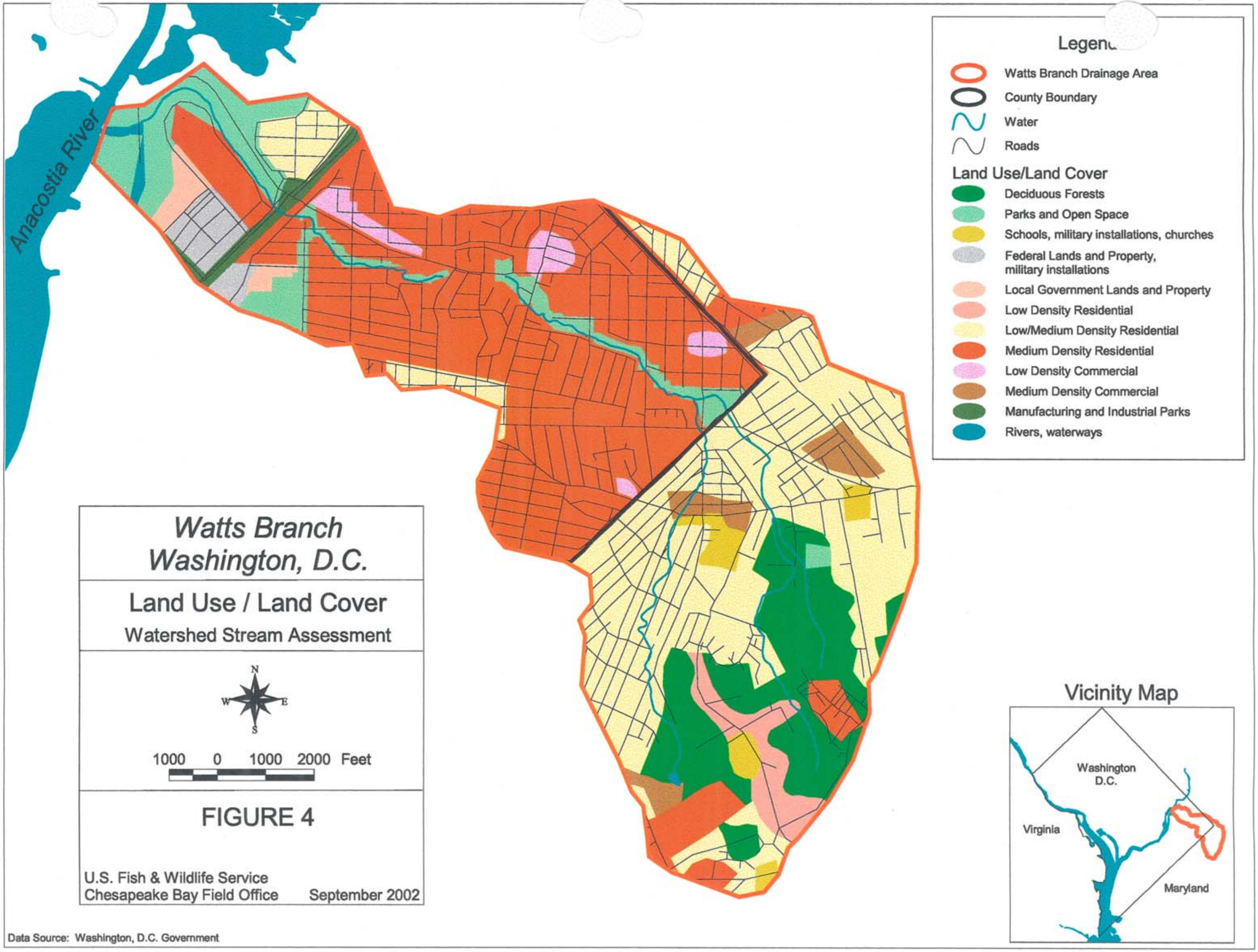
FIGURE 3
U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
September 2002
Data Source: Washington, D.C. Government



Legend
Watts Branch Drainage Area
County Boundary
Water
Roads
Land Use/Land Cover
Deciduous Forests
Parks and Open Space
Schools, military installations, churches
Federal Lands and Property, military installations
Local Government Lands and Property
Low Density Residential
Low/Medium Density Residential
Medium Density Residential
Low Density Commercial
Medium Density Commercial
Manufacturing and Industrial Parks
Rivers, waterways
Anacostia River
Watts Branch
Washington, D.C.
Land Use / Land Cover
Watershed Stream Assessment
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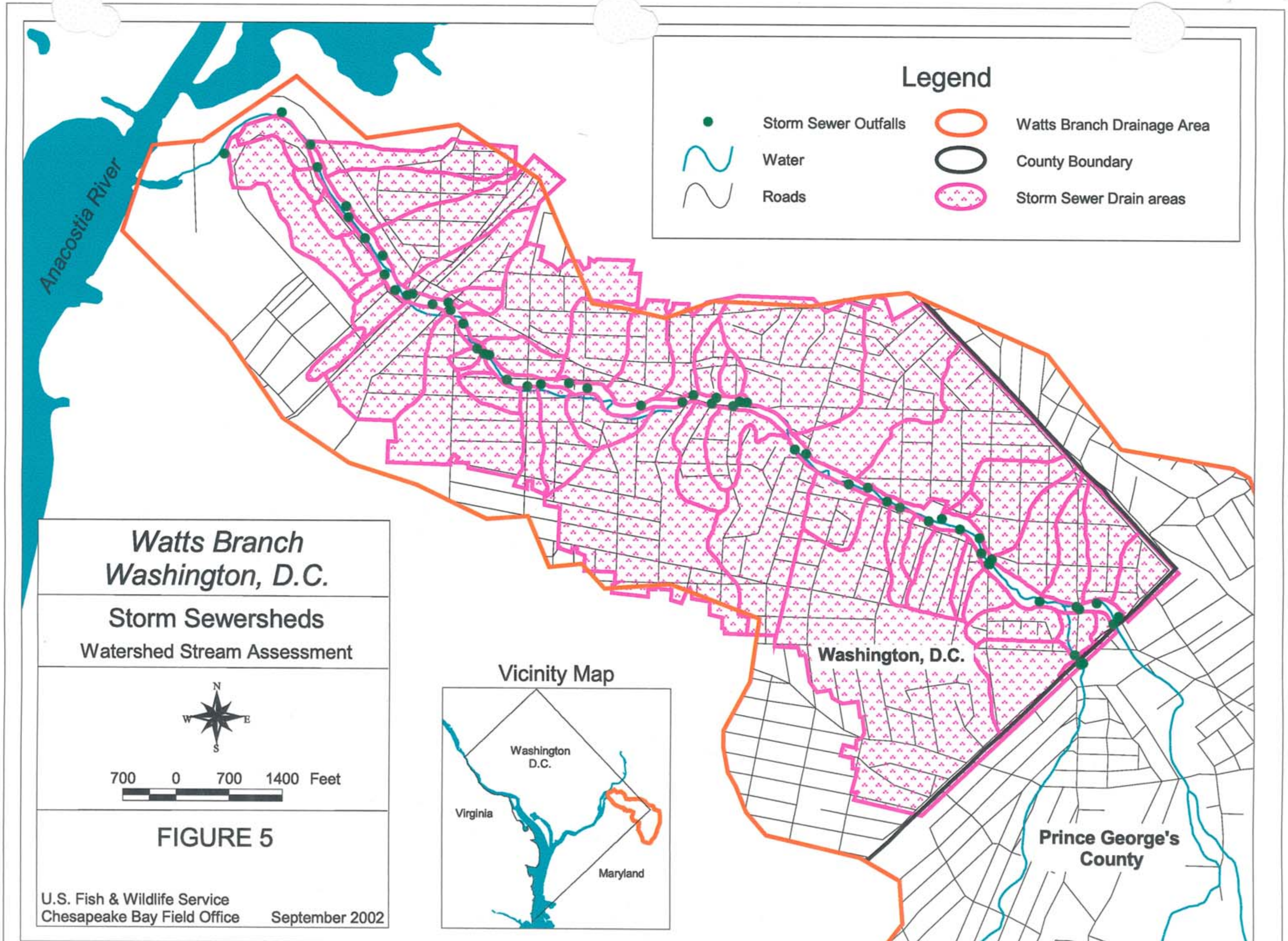
1000 0 1000 2000 Feet
FIGURE 4
U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
September 2002
Vicinity Map
Washington D.C.
Virginia
Maryland
Data Source: Washington, D.C. Government



Data Source: Washington, D.C. Government

The canopy tree species are dominated by box elder (*Acer negundo*), river birch (*Betula nigra*), and red maple (*Acer rubrum*). The understory plant species are dominated by box elder (*Acer negundo*) and multiflora rose (*Rosa multiflora*). During the riparian assessment, the ground plant species were dominated by garlic mustard (*Alliaria petiolata*) and grass species (*Gramineae sp.*). The Service observed several exotic and invasive species, including multiflora rose, garlic mustard, tree-of-heaven (*Ailanthus altissima*), Japanese knotweed (*Polygonum cuspidatum*) and bamboo. A narrow riparian buffer is usually indicative of a low plant diversity and/or density, which contributes to a marginal riparian habitat, especially for forest wildlife species.

Similar to the other riparian characteristics, riparian rooting depth is highly variable within Watts Branch. Riparian rooting depth is an important component in providing physical stability to the stream. In areas with high stream bank heights and/or entrenchment, the lack of vegetation or shallow rooting depths may result in lateral instability and subsequent sediment loads from bank erosion.

The riparian buffer is necessary to maintain a healthy aquatic habitat. It provides shading, habitat in the form of large woody debris, and nutrients in the form of organic biomass. The low amount of shading and lack of woody debris are significant concerns regarding the riparian buffer and aquatic habitat of Watts Branch. Stream shading is important for two major reasons: 1) it regulates water temperature; and 2) it reduces the growth of algae. Both of these factors affect the concentration of dissolved oxygen in the stream, which is critical to the survival of aquatic species. Large woody debris provides instream cover and habitat for aquatic species. Although the Service did observe some large woody debris, the lack of large woody debris may be due to the narrow or nonexistent riparian buffer, and the possible removal of large woody debris to maintain the proper function of the culverts and bridges.

B. Stream Geomorphology

Due to the impacts of urbanization and channelization, the conditions at Watts Branch represent a departure from its potential stable condition. In some areas, higher peak discharges and flow velocities have resulted in an increased sediment transport capacity. Where the sediment transport capacity exceeds the sediment supply, the stream is degrading. Additionally, where sediment supply exceeds the sediment transport capacity, the stream is aggrading.

The Service conducted detailed stream surveys of five representative stream reaches located on the main-stem of Watts Branch. The remaining eleven reaches were similar to other representative reaches and therefore, their stream classifications and characteristics were extrapolated from the surveyed reaches. Reaches WB-01 to WB-12 are in the Upper Reach of Watts Branch, located between Southern Avenue and Kenilworth Avenue. Reaches WB-13 to WB-16 are in the Lower Reach, located between Kenilworth Avenue and the Anacostia River (Figure 6). These sixteen reaches total 16,800 linear feet of stream. Table 2 provides reach lengths and Rosgen stream type classifications.

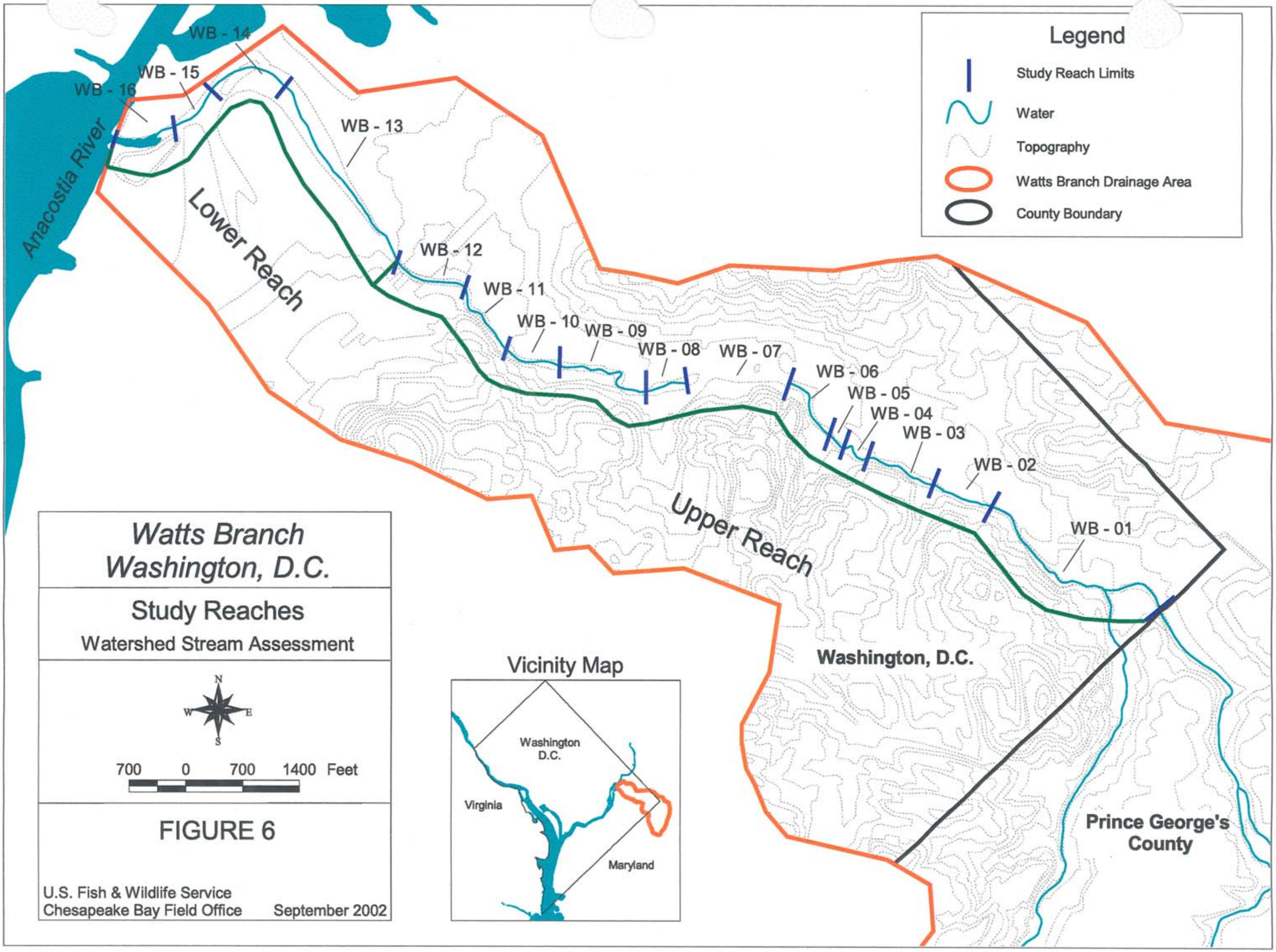
Table 2. Watts Branch Reach Information							
Reach		Stream Type	Stream Length	Reach		Stream Type	Stream Length
Upper Reach	WB-01	F4	2,717	Upper Reach	WB-09	F4	1,343
	WB-02	F4	779		WB-10	F4	741
	WB-03	F4	905		WB-11	F4	965
	WB-04	F4	401		WB-12	F4	941
	WB-05	F4	241	Lower Reach	WB-13	F4	2,588
	WB-06	F4	884		WB-14	F4	1,082
	WB-07	Culvert	1,343		WB-15	F4	665
	WB-08	F4	499		WB-16	F4	785

The Natural Resources Conservation Service designed and constructed a stream stabilization project located in the Upper Reach, Reach WB-01 (Figure 6). The stabilization techniques used for this project include imbricated rip-rap and cross-vanes. The Service is monitoring the effectiveness of this project for a five-year period and will provide project evaluation reports on an annual basis.

1. Upper Reach of Watts Branch

The Upper Reach of Watts Branch is significantly impacted by urbanization and stream alterations. The flow regime for the stream has changed in response to the urbanization and land use changes. Changes to the flow regime include increased stormwater runoff, peak discharges, and increased flashiness. The stream has also been channelized and its floodplain lost due to floodplain fill and/or channel capacity enlargement.

In response to the urbanization and stream alterations, the stream is actively adjusting to accommodate the higher discharges within the channel. These adjustments are indicative of the significant instability found in the Upper Reach of Watts Branch. Reaches WB-01 to WB-09 are both vertically and laterally unstable. Reaches WB-10 to WB-12 are stable with localized areas of instability. The Service identified approximately 2,647 linear feet of moderate to high erosion along the stream, which is approximately 25 percent of the Upper Reach. The moderate to high erosion is due to a variety of causes, including moderate to extreme bank erosion hazard indices and moderate to very high near bank shear stress. Some factors which contribute to an increased bank erosion hazard index and near bank shear stress are higher entrenchment, a steeper stream slope from channelization, limited bank and riparian vegetation, less consolidated bank materials, and higher shear stress in the near bank one-third area of the channel cross section. Some of the stream stability is derived from existing stabilization projects, including rip-rap, gabion baskets, and concrete block revetments. This reach has approximately 11,074 linear feet of the stream



Data Source: Washington, D.C. Government

stabilization, which is approximately 50 percent of the Upper Reach. The length of stabilization is reported for both banks, where applicable, and thus may exceed the length of the reaches. The stability from these revetments is temporary and some areas are undermined and are falling into the stream. This is a significant concern because the stream has a very high erosion potential. Failure of these revetments will likely result in further lateral erosion and sediment contributions into the stream.

Stream adjustments affect channel dimensions, meander pattern, and longitudinal profile. To accommodate the higher discharges within the channel, the stream has incised and entrenched, reducing access to the floodplain. Higher flows are required to breach the top of bank to access the abandoned floodplain. Since the stream no longer has an active floodplain, it will laterally erode to increase channel capacity. This adjustment will result in a wider stream width and a higher width/depth ratio. The higher width/depth ratio results in shallower flow depths across the stream. Because the stream is channelized, there is virtually no meander pattern or stream geometry (*e.g.*, sinuosity, beltwidth, radius of curvature, meander wavelength). Channelization reduces the stream length, which results in an increase in stream slope.

For this reach, the sediment transport capacity generally exceeds the sediment supply, causing the stream to degrade. This degradation and changes in the channel dimensions, meander pattern, and longitudinal profile impact bed feature development. Most of the bed features are poorly defined, with only a few moderately to well-defined features. In general, the riffles are short, the runs are shallow, and the pools are shallow and irregularly spaced along the longitudinal profile.

Historically, the stable stream form for this reach was mostly likely a meandering stream with a well-developed floodplain. However, channelization and urbanization caused the stream to vertically and laterally erode in an attempt to re-establish a stable channel dimension, meander pattern, and longitudinal profile. Currently, the stream is entrenched with a high width/depth ratio (*i.e.*, Rosgen F stream type). If allowed to freely evolve, the stream would continue to widen until it establishes a proper beltwidth. Beltwidth is the widest extent a stream meanders across the stream valley. The stream would also begin to aggrade, creating a new floodplain within the existing degraded stream. As the floodplain develops, the stream would become less entrenched, with a lower width/depth ratio.

This reach has a poor instream habitat rating, due primarily to poor water quality and low habitat diversity. Hydrocarbons, heavy metals, pesticides, sewage, and sediment are the primary causes for the poor water quality. The low habitat diversity is the result of marginal bed feature development, shallow water depths, and lack of instream cover (*e.g.*, large woody debris, and overhanging vegetated banks).

Riparian buffer widths range from 0 to 250 feet, with the average buffer width less than 10 feet. These averages frequently represent one side of the stream, and it is common to find a narrow or nonexistent buffer along the other bank. Approximately 45 percent of the Upper Reach has no buffer. In areas with high stream bank heights and/or entrenchment, the lack of vegetation and/or shallow rooting depths may result in lateral instability and subsequent sediment loads from bank erosion, particularly at higher flows. Areas of moderate to extreme erosion were commonly associated with a lack of vegetation and/or shallow rooting depths.

2. Lower Reach of Watts Branch

The Lower Reach of Watts Branch is also significantly impacted by urbanization and stream alterations. The impacts associated with urbanization and stream alterations are similar to those discussed above in the Upper Reach.

In response to the urbanization and stream alterations, the stream made adjustments to accommodate the higher discharges within the channel. However, the Lower Reach is generally vertically aggrading and laterally stable. The lateral stability is indicated by lower bank erosion hazard indices and lower near bank shear stresses. Some of the factors contributing to the increased bank stability are lower entrenchment, lower stream slope, and more bank and riparian vegetation. Although the majority of stream is laterally stable, the Service identified approximately 1,279 linear feet of moderate to high bank erosion, which is approximately 25 percent of the Lower Reach. Compared to the Upper Reach, this reach derives less of its stream stability from stream stabilization projects. The Service identified 1,136 linear feet of bank stabilization, consisting of mortared rip-rap. The rip-rap comprises approximately 13 percent of the Lower Reach. As noted in the Upper Reach, the long term stability of this revetment is questionable.

The channel dimensions, meander pattern, and longitudinal profile reflect stream changes to accommodate the higher discharges within the channel. Although the stream is aggrading, the stream still has a high width/depth ratio and entrenchment. As the stream aggrades, the stream may begin to laterally adjust to accommodate higher flows, which will compromise the future lateral stability of the stream. Because the stream is channelized, there is virtually no meander pattern or stream geometry. Although channelization increases stream slope, the lower slope in this reach is associated with its proximity to the Anacostia River.

The higher width/depth ratio and lower slope reduces the sediment transport capacity, thus causing this reach to aggrade. Most of the bed features in this reach are poorly defined, with short riffles, shallow runs, and the shallow irregularly spaced pools.

Similar to the Upper Reach, the stable stream form for this reach was most likely a meandering stream with a well-developed floodplain and wetland system. Due to channelization and urbanization, the stream is attempting to re-establish a stable channel dimension, meander pattern, and longitudinal profile. Similar to the Upper Reach, the stream has a high width/depth ratio and entrenchment.

For this reach, the instream habitat rating is poor, due primarily to poor water quality and low habitat diversity. The reason for the poor water quality and low habitat diversity are similar to those discussed above in the Upper Reach.

Riparian buffer widths range from 0 to 200 feet, with the average buffer width less than 30 feet. These averages frequently represent one side of the stream, and it is common to find a narrow or nonexistent buffer along the other bank. Approximately 12 percent of the Lower Reach has no buffer.

3. Rosgen Stream Type Characteristics

Both the Upper and Lower Reach of Watts Branch are characterized as an F4 Rosgen stream type. In general, the F4 stream type is an entrenched, deeply incised, riffle/pool stream, with a moderate to a high width/depth ratio and a slope generally less than 2 percent (Rosgen 1996). The stream substrate consists primarily of gravel and sand, with gravel the dominant material. The potential for erosion and sediment input are high and dependent on stream stability. Additionally, the F4 stream type has a poor recovery potential on its own, even if the cause of instability is corrected (Rosgen 1996). Although depositional features are common in F4 stream types, they were less frequent in reaches with higher entrenchment and lower width/depth (*i.e.*, WB-01, WB-02, and WB-04). These conditions hinder bar development because of increased flow velocities and sediment transport capacities, particularly at higher flows. Depositional features are more common in the Lower Reach because of the lower stream slope, lower entrenchment, and higher width/depth ratio.

C. Bankfull Determination

The bankfull discharge is the discharge or the range of discharges which is responsible for the formation and maintenance of the stream channel dimensions, planform patterns, and longitudinal profile. An accurate determination of the bankfull discharge is one of the most critical aspects of assessing an impaired stream and developing an appropriate and effective stream restoration design. Although urbanization tends to cause higher peak discharges in streams, the bankfull discharge may not increase but instead become more frequent. Typically, the recurrence interval of bankfull is between one and two years in rural streams. However, the recurrence interval of bankfull in urban streams can be as low as 0.45 years (Brunner 1999).

Because Watts Branch must accommodate all discharge events within its banks, the resulting high stream velocities and stream power have diminished the formation of typical geomorphic features; which are less defined and inconsistent. The Service identified a few geomorphic features in the stream, with bankfull most likely the lowest feature. The development of the higher geomorphic features may be indicative of the higher flows confined in the entrenched stream or these features may represent relic bankfull indicators abandoned by the stream as it degrades.

The calculated bankfull discharges range from 60 to 80 cfs at the confluence of Watts Branch and the Anacostia River, depending on the calculated Manning's "n". These discharges were checked against the preliminary western coastal plain regional curve developed by the Service. To further validate the bankfull determination, the Service recommends installation of staff plates and crest stage gages at strategic locations along Watts Branch. These gages will allow the Service to better determine flow velocities and discharges during higher discharge events.

V. PROBLEM IDENTIFICATION

The Service identified problem areas by developing geomorphic cause and effect relationships within Watts Branch. The Service focused on identifying the natural and anthropogenic processes and how these processes influenced stream stability and habitat conditions.

A. Watershed Processes

The effects of watershed processes on stream stability and habitat conditions in Watts Branch are typical of most urban watersheds. The majority of these effects are directly related to how land use activities and land cover within the watershed influence the watershed hydrology. The amount of impervious surface within the Watts Branch watershed causes high stormwater runoff, high peak stream discharges, high flow velocities, high flow flashiness, low groundwater recharge, low base flows, poor water quality, high stream instability, poor instream habitat and variations in sediment production (Gregory 2002). This change in the watershed hydrology has and continues to greatly influence stream channel processes, instream habitat, and water quality in Watts Branch.

B. Stream Morphology Processes

1. Stream Processes

Stream processes are not only influenced by a change in the watershed hydrology but also by stream channelization. Essentially 100 percent of the stream in the Upper Reach has been channelized or altered. Channelization affects stream stability by reducing plan form resistance and increasing the slope of the stream. The stream loses its ability to dissipate energy along the meandering plan form and bed features of the stream. In response to this loss, and coupled with a change in the watershed hydrology, the stream vertically erodes, causing stream incision and entrenchment. The stream will continue to vertically erode until one of two situations occurs: 1) the stream bank height exceeds the critical bank height for stability causing mass bank failure or 2) the stream encounters resistant bed materials and cannot erode. When one of these conditions occurs, the stream may instead laterally erode to increase floodplain area which increases the width/depth ratio of the stream.

In the Upper Reach of the Watts Branch, both of the above situations have occurred and continue to occur. The Upper Reach lost access to its floodplain due to fill and/or channel capacity enlargement. A floodplain attenuates higher flow velocities, thus reducing stream power and erosion during higher discharges. The loss of floodplain caused the stream to incise and entrench because it was forced to accommodate higher discharges within the active channel. Additionally, the channelization reduced the stream length and increased the stream slope, causing higher flow velocities which also promotes vertical and lateral erosion.

The Lower Reach, historically, was degraded in a manner similar to the Upper Reach, and for the same reasons. However, this reach appears to be aggrading because the sediment supply is exceeding the sediment transport capacity. An increase in sediment supply is likely the result of stream instability in the Upper Reach. A decrease in the sediment transport capacity in the Lower

Reach is the result of two major conditions: 1) an increase in width/depth ratio and 2) a decrease in stream slope, due to the stream's proximity to the Anacostia River. Additional stream bank erosion may occur as the stream continues to aggrade and then attempts to develop a floodplain and meander pattern.

2. Sediment Processes

Stream instability directly influences both sediment supply and sediment transport. Sediment supply increases as a result of stream bank and bed erosion. Typically, the bed material size increases and deposits in the wider portions of the stream. Since the stream energy has decreased from channel over-widening, these depositional features are constantly shifting and may remain as temporary storage for years (Schueler, 1987). These shifting bars generally aggravate streambank erosion by deflecting flows directly into streambanks. The Service observed that the Upper Reach of Watts Branch is in a stream-degradation trend, while the Lower Reach is in a stream-aggradation trend.

3. Urban Infrastructure

Urban infrastructures (*e.g.*, utility lines and stormwater outfalls) can further aggravate stream instability. Throughout Watts Branch, numerous utility lines parallel or cross the stream. These utility lines cause a variety of problems and potential restoration concerns for the stream, including obstructions to fish passage and stream confinement. During the field assessment, the Service identified seven exposed sewer crossings where the stream has vertically and laterally eroded. Often, there is a significant drop in the water surface downstream of the sewer crossing causing a fish passage obstruction. The proximity of the stream to utility lines may also affect potential restoration alternatives with respect to planform realignment and bank grading.

The extensive number of outfalls, and their positioning and orientation in relation to the stream has caused extensive vertical and lateral stream erosion. Outfalls are typically elevated above the stream bed and oriented nearly perpendicular to the stream flow. In reaches with the high stream banks and/or a lack of bank vegetation, the effects of the uncontrolled stormwater discharges are typically more severe. From stormwater information provided by D.C., the Service identified 41 stormwater outfalls and 13 pipes which discharge into the D.C. portion of Watts Branch (Figure 5). The 13 pipes discharge into existing box culverts located in Reaches WB-01, WB-07, and WB-08. Stormwater runoff transports contaminants from impervious surfaces, and discharges them into the stream from these outfalls. Although the sewershed map identified no combined stormwater outfalls in the Watts Branch watershed, the Service observed several outfalls discharging grey water and potential industrial wastewater during rain events and base flow conditions. The Service also observed accumulation of sewage in some of the pools in the stream.

4. Water Quality

Water quality conditions are impacted by three primary sources within Watts Branch: 1) sewage leaks, 2) stormwater runoff, and 3) increased sediment supply. According to a report by D.C. DOH (2000), persistent sewage line leakage, sewage line breaks, and stormwater discharges into

Watts Branch have impaired water quality, degraded aquatic habitats, and produced a public human health risk. Sewage leaks also impact the stream by promoting high levels of algae and harmful bacteria. As stated above, the Service observed greywater and potential industrial wastewater discharging from several stormwater outfalls and in several pools in the stream.

In urban watersheds stormwater runoff is the dominate pathway for pollutants accumulated on urban impervious surfaces to reach the stream during storm events (Schueler 1991). Contaminants readily bind to soil particles and stormwater runoff dislodges or dissolves the pollutant particles, carrying these pollutants directly into the stream systems (Nix 1994). Bank erosion can also be a significant pathway for contaminants and nutrients to enter the stream. In general, pollution concentrations in urban streams are one to two orders of magnitude greater than those found in forested areas. The degree of pollutant loading is directly related to the percent of imperviousness in the watershed (Schueler 1987). Typical pollutants found in urban watersheds include polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), heavy metals, pesticides, nitrogen, phosphorus, bacteria, organic matter, and trash debris. Sources of pollutants in Watts Branch include, roadways, vehicles, industrial activities, landfills, sewerage leaks, decaying vegetation, soil erosion, fertilizers, pesticides, deicing agents, and general litter. The Service observed indicators of many of these pollutants throughout Watts Branch.

Excessive amounts of sediment also have a significant impact on Watts Branch. The primary sediment source identified in this assessment is instream erosion. During the field assessment, the Service identified 3,926 linear feet of moderate to extreme bank erosion, approximately 25 percent of the D.C. portion of Watts Branch. A preliminary assessment/site investigation conducted in 2000 by Ecology and Environmental, Inc., found elevated concentrations of contaminants (*i.e.*, PAHs and arsenic) in surface soils. The investigation also found sediment concentrations of contaminants (*i.e.*, PCBs, PAHs, and pesticides) exceeding screening levels established to protect the most sensitive aquatic organisms (Ecology and Environmental 2000). Excessive suspended and bed load sediments can impair aquatic reproduction, destroy feeding areas, and smother aquatic species. Suspended sediments also reduce the amount of light available to submerged aquatic vegetation. Elevated water temperatures resulting from poor stream shading and shallow water depths also impact water quality. Elevated water temperatures reduce the available dissolved oxygen, which is critical to the survival and successful reproduction of aquatic species.

The poor water quality of Watts Branch is reflected in the benthic macroinvertebrate and fish communities. Benthic macroinvertebrate surveys conducted in 1998 by American University determined that Watts Branch has a very poor biotic integrity rating. This very poor rating is due to low density and diversity of the macroinvertebrate community, which consists primarily of pollution tolerant species. The fish survey conducted in 1998 by American University in the nontidal portion of Watts Branch also revealed a very poor biotic integrity rating, for similar reasons. The fish survey conducted in the tidal and near tidal portions of the stream has a fair biotic integrity rating, where fish are able to migrate to the downstream portions of the Watts

Branch from the Anacostia River (D.C. Department of Health, Unpublished Data).

The poor water quality of Watts Branch contributes to the degradation of the Anacostia River's water quality. The Anacostia River has elevated concentrations of hazardous contaminants, including polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), heavy metals, and pesticides. The concentrations of these contaminants are sufficiently high enough to harm benthic invertebrates and fish, and may also impair their reproductive success (NOAA 2002).

5. Riparian Buffer

The most significant problems associated with the riparian buffer are channel incision and narrow buffer widths. Riparian buffer widths range from 0 to 250 feet with the average buffer width in the Upper Reach and Lower Reach less than 10 feet and 30 feet, respectively. These averages frequently represent one side of the stream, and it is common to find a narrow or nonexistent buffer along the other bank. Approximately, 45 percent of the Upper Reach has no riparian buffer and 12 percent of the Lower Reach has no buffer. In areas with high stream bank heights and/or entrenchment, the lack of vegetation and/or shallow rooting depths may result in lateral instability and subsequent sediment loads from bank erosion, particularly at higher flows. Areas of moderate to high erosion were commonly associated with a lack of vegetation and/or shallow rooting depths.

6. Instream Habitat

The poor aquatic habitat for Watts Branch is due to impaired water quality, stream instability, marginal bed feature development, high width/depth ratios of the stream, and the lack of instream cover. In addition, culverts, utility crossings, and high width/depth ratios pose significant obstacles to fish passage. The Watts Branch water quality characteristics are discussed in the Water Quality section of this report. The bed features found in Watts Branch include riffles, runs, and pools. During the stream assessment, the Service found poorly to moderately developed bed features. Reaches with poorly developed bed features lack habitat diversity, which is critical for a healthy and diverse aquatic community. High width/depth ratios indicate a very wide bankfull width compared to the bankfull depth. In general, reaches with a high width/depth ratio have shallow riffles, runs, and pools. These reaches provide poor aquatic habitat, lack habitat diversity, and promote elevated water temperatures. The stream lacks instream cover, often provided by large woody debris, and overhanging vegetated banks.

Concrete box culverts are a significant obstacle to fish passage because they have low surface roughness, a high width/depth ratio and a water depth too shallow to allow passage. Concrete and corrugated steel pipe culverts often concentrate flows during storm events and result in high velocities which may prevent passage. Reach WB-07, which contains two concrete box culverts, is a major obstacle to fish passage because of the grade change at the outlet, and its size and length. Utility crossings can also obstruct fish passage, especially when there is a significant change in water surface elevation downstream of the crossing. Reaches with high width/depth ratios have a water depth which may be too shallow for fish passage.

7. Site-Specific Problems

The Service has identified site-specific problems associated with each reach (Table 3). These problems are the result of existing or potential conditions, which are or could impact stream stability and/or habitat.

Table 3. Watts Branch Problem Identification

Problem Description	Reaches															
	WB-01	WB-02	WB-03	WB-04	WB-05	WB-06	WB-07	WB-08	WB-09	WB-10	WB-11	WB-12	WB-13	WB-14	WB-15	WB-16
Poor Water Quality	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sewage Leaks	X	X						X				X				
Channelization or Alteration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Revetments - Single Bank	X	X	X	X	X			X	X	X	X					
Revetments - Both Banks	X	X		X						X	X	X		X		
Revetments - Entire Stream							X					X				
Bank Erosion	X	X	X	X	X	X		X	X	X	X		X		X	X
Bed Erosion	X	X	X	X	X	X		X	X							
Stream Aggradation								X	X				X	X	X	X
Floodplain Loss	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stream Confinement	X	X	X	X	X	X	X	X	X	X	X	X				
Stormwater Outfalls	X	X	X			X	X	X	X	X	X	X	X	X	X	
Utilities Lines and Crossings*	X		X		X	X		X	X			X				
Poor Aquatic Habitat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Obstacles to Fish Passage	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Poor Riparian Buffer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Urban Debris	X	X	X	X	X	X	X	X	X	X	X	X	X	X		

*: Requires additional information.

VI. PRIORITY RATING

Because of the severe impairment of Watts Branch, the Service is using a restoration priority rating of high, higher, and highest to rate reaches (Table 4 and Figure 7). The Service used a variety of criteria to determine instability and the relative severity of the instability, including channel shear stress, bank erodibility, stream stability, stream entrenchment and incision. The Service also considered stream sensitivity characteristics based on management interpretations of various stream types presented in Rosgen (1996), including disturbance sensitivity, recovery potential, bank erosion potential, and sediment potential.

Table 4. Watts Branch Restoration Priority Rating					
Reach		Priority Rating	Reach		Priority Rating
Upper Reach	WB-01	Highest	Upper Reach	WB-09	Higher
Upper Reach	WB-02	Highest	Upper Reach	WB-10	High
Upper Reach	WB-03	Highest	Upper Reach	WB-11	High
Upper Reach	WB-04	Highest	Upper Reach	WB-12	High
Upper Reach	WB-05	Highest	Lower Reach	WB-13	High
Upper Reach	WB-06	Higher	Lower Reach	WB-14	High
Upper Reach	WB-07	Higher	Lower Reach	WB-15	High
Upper Reach	WB-08	Higher	Lower Reach	WB-16	High

The Service will work with DOH and other stakeholders to evaluate the opportunities for outfall closures or retrofits. The Service has prioritized the closure of outfalls, based on identified stream impacts and outfall size (Table 5 and Figure 8). The Service prioritized the outfall sizes based on the assumption that larger outfalls are more likely to cause stream instability and contribute more contaminants to the stream. The Watts Branch Outfall Priority table identifies the number and priority rating of the outfalls in each reach.

Table 5. Watts Branch Outfall Priority																
Outfall Ratings	Reaches															
	WB-01	WB-02	WB-03	WB-04	WB-05	WB-06	WB-07	WB-08	WB-09	WB-10	WB-11	WB-12	WB-13	WB-14	WB-15	WB-16
Highest	7	0	1	0	0	2	3	0	1	2	2	2	3	0	1	0
Higher	3	2	2	1	0	0	3	0	0	0	0	1	4	1	0	0
High	2	1	1	0	0	0	1	1	1	1	2	0	3	0	0	0

Approximately, 44 percent of the outfalls are identified as highest priority for closure or retrofit. During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for those outfalls.

The Service will work with DOH and other stakeholders to develop comprehensive and watershed based source control solutions. The Service has prioritized potential sub-sewersheds for source control investigation, based on identified stream impacts, sub-sewershed size, and existing land use(s) (Table 6 and Figure 9). Similar to the outfall size prioritization, the Service evaluated the sub-sewershed sizes based on the assumption that larger sub-sewersheds are more likely to contribute higher stormwater discharges at higher velocities and more contaminants to the stream. The Watts Branch Stormwater Priority table identifies the number and priority of sub-sewersheds in reach.

Table 6. Watts Branch Stormwater Priority

Outfall Ratings	Reaches															
	WB-01	WB-02	WB-03	WB-04	WB-05	WB-06	WB-07	WB-08	WB-09	WB-10	WB-11	WB-12	WB-13	WB-14	WB-15	WB-16
Highest	0	0	2	0	0	2	2	0	0	0	0	2	0	0	0	0
Higher	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0
High	1	2	2	0	0	0	5	1	2	3	3	1	7	1	0	0

Approximately, 49 percent of the sub-sewershed area has been identified as highest priority for stormwater source control. During the design phase, the Service and DOH will determine the feasibility of source control in those sub-sewersheds.

VII. GENERAL RESTORATION RECOMMENDATIONS

Proposed restoration alternatives are discussed below and a summary of problems with suggested restoration alternatives is provided in Table 5.

Table 5. Watts Branch General Restoration Recommendations

	Problems	Restoration Alternatives
Water Quality	1) Heavy Metals, PAHs, PCBs, and Pesticides	1) Divert Road Runoff 2) Close Outfalls 3) Remove Urban Trash (*e.g.*, car batteries)
Water Quality	2) Sewage Leaks	1) Install New Sewer Line 2) Encase Existing Sewer Line
	3) Sediment	1) Develop a Stable Stream Dimension, Pattern, and Longitudinal Profile 2) Use Physical Restoration Techniques which Reduce Bank Stress

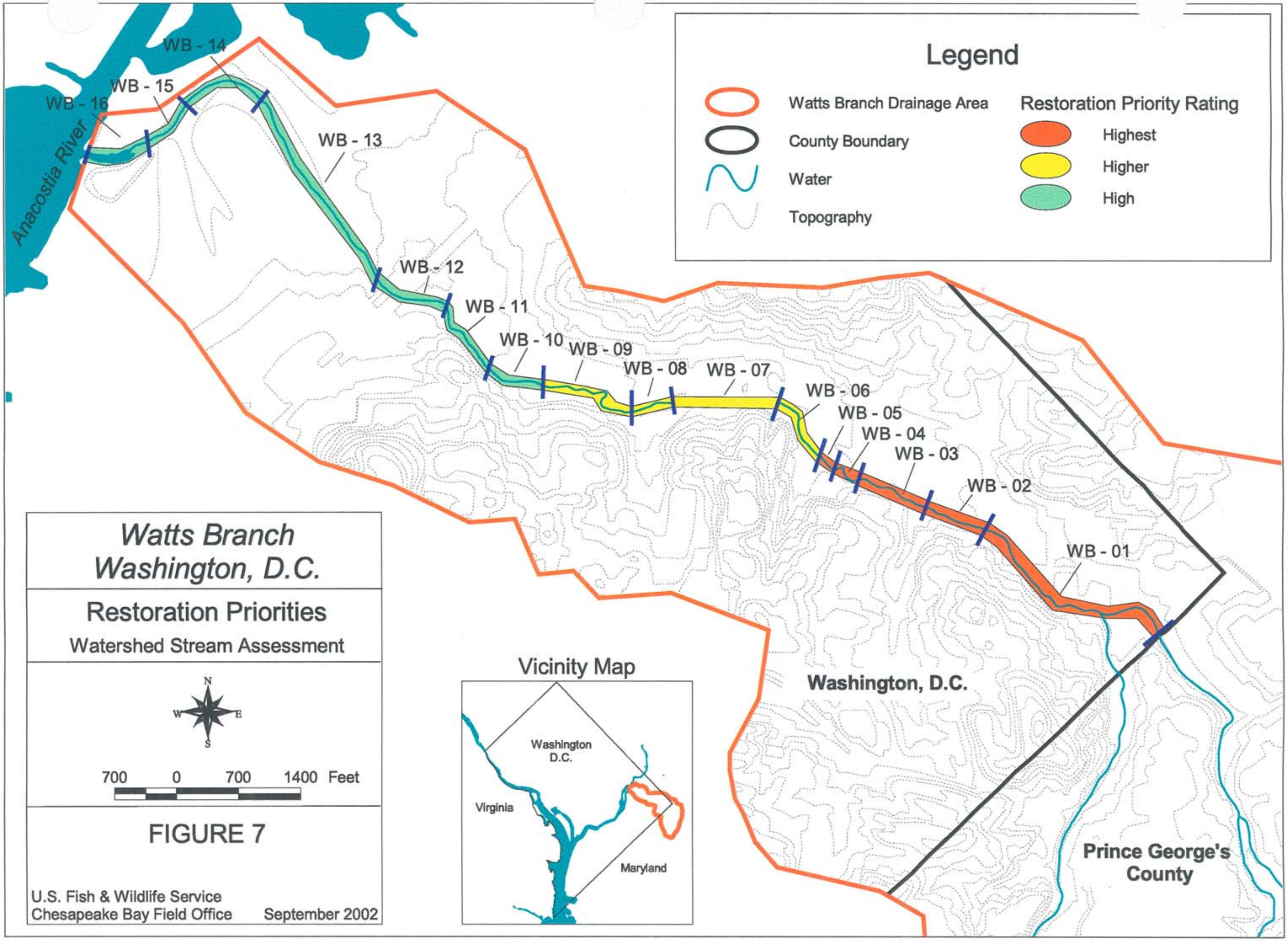
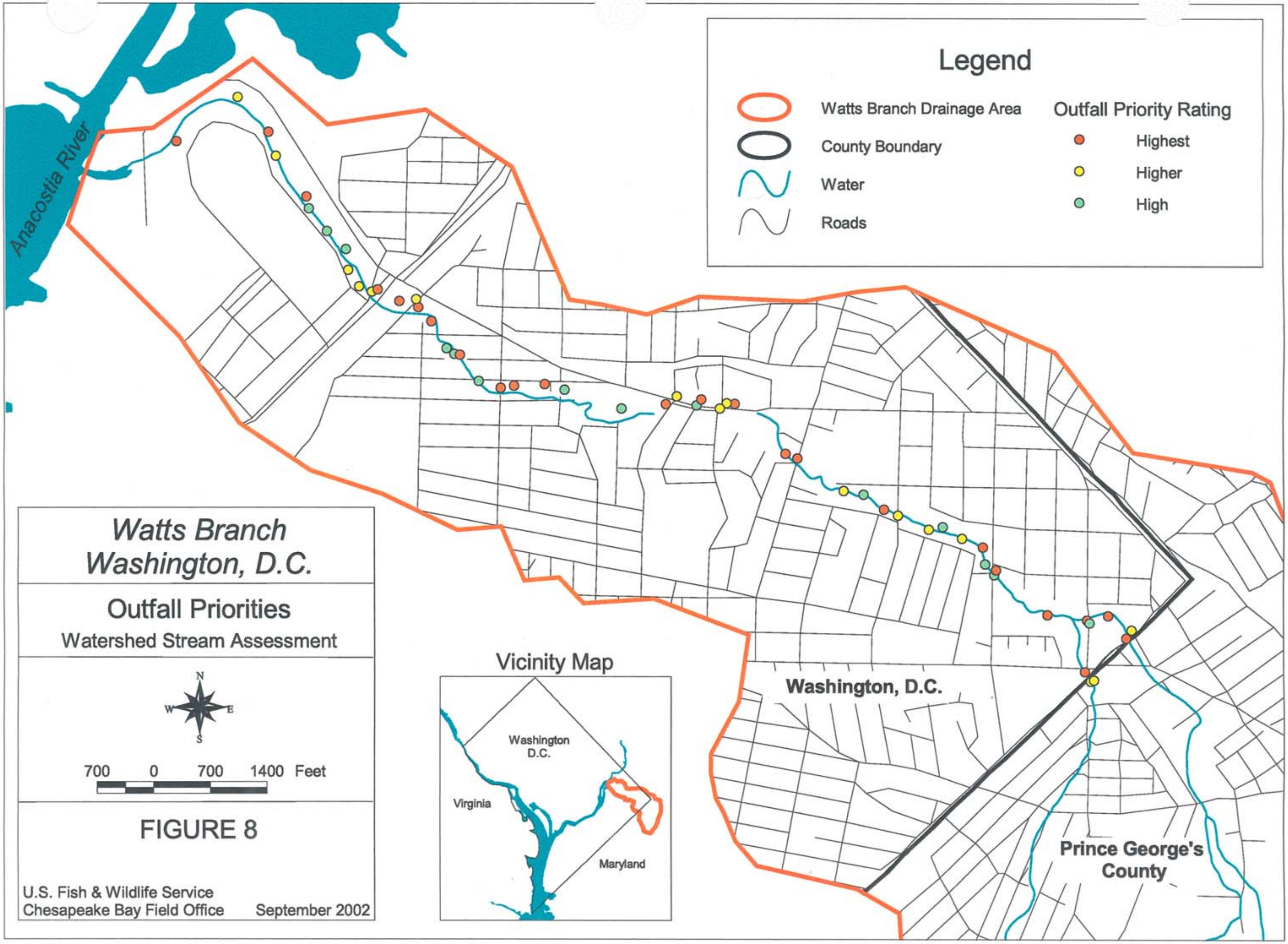


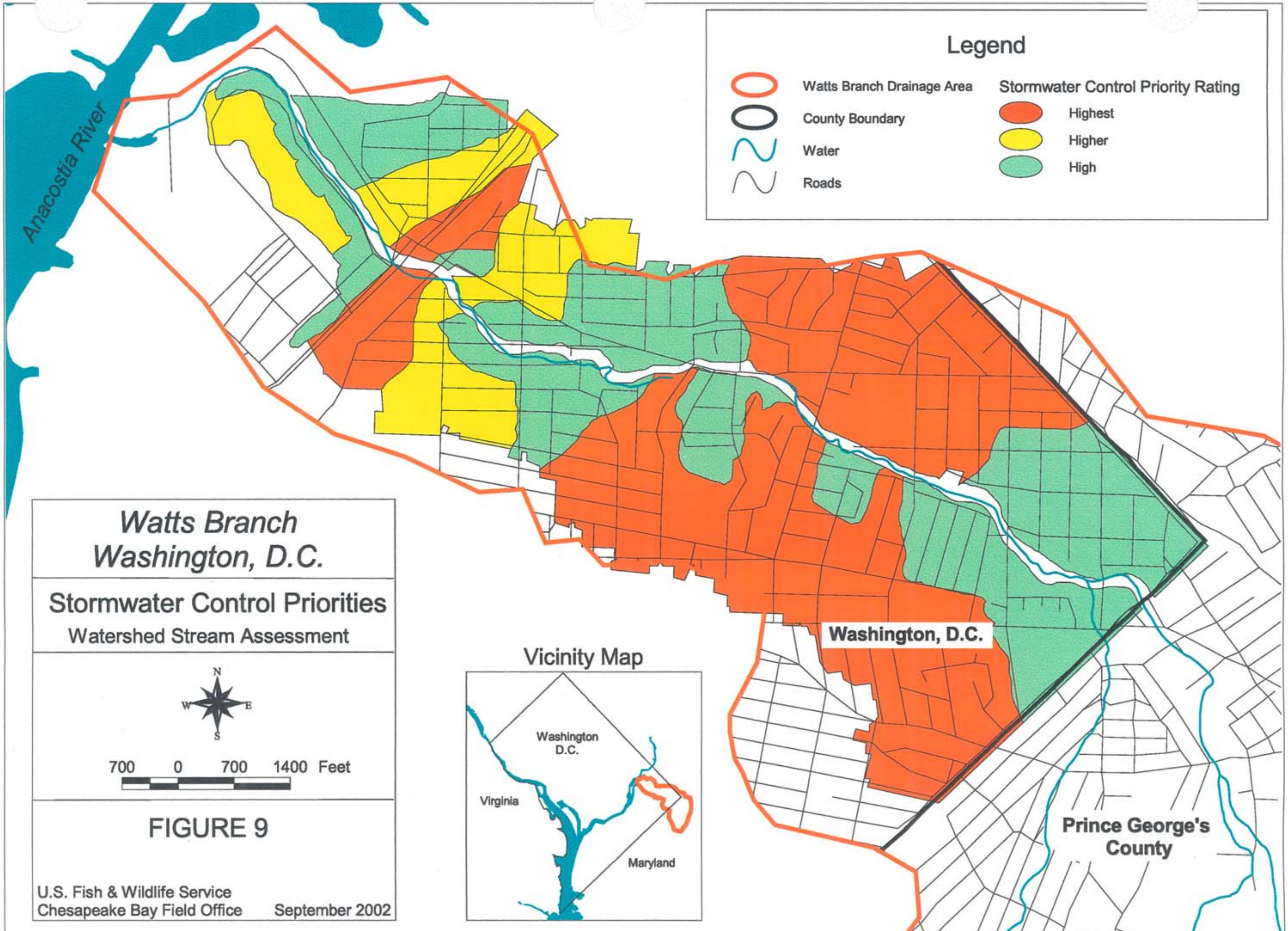
FIGURE 7

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
September 2002

Data Source: Washington, D.C. Government



Data Source: Washington, D.C. Government



Data Source: Washington, D.C. Government

Table 5. Watts Branch General Restoration Recommendations		
	Problems	**Restoration Alternatives**
	3) High Water Temperatures	1) Establish Riparian Buffer 2) Develop a Stable Stream Dimension, Pattern, and Longitudinal Profile 3) Reduce Nutrient Load
Stream Stability	1) Stable Stream Dimension, Pattern, and Longitudinal Profile	1) Create of a Stable Meandering Stream in the Historic Floodplain 2) Establish Stream and Floodplain within the Existing Stream 3) Establish Stream and Floodprone Area within the Existing Stream 4) Stabilize Stream in Place
Outfalls and Utility Lines	1) Outfalls	1) Close Outfalls 2) Retrofit Outfalls to Attenuate Stormwater Flows
	2) Utility Lines	1) Re-Align Utility Lines 2) Use Grade Control Structures to Protect Utility Crossing 3) Restore Fish Passage
Aquatic Habitat	1) Water Quality	1) Address Contaminant, Nutrient, Sediment, and Temperature Concerns
	2) Stream Stability	1) Develop a Stable Stream Dimension, Pattern, and Longitudinal Profile
	3) Instream Cover	1) Incorporate Instream Cover with the Restoration Techniques 2) Establish Bank Vegetation
	4) Fish Passage	1) Use Restoration Structure to allow Fish Passage 2) Research Additional Alternatives
Riparian Habitat	1) Reforestation and Riparian Enhancement	1) Establish and/or Expand Riparian Buffer 2) Plant Native Vegetation

A. Water Quality

The main source of heavy metals, PAHs, PCBs, and pesticides is most likely stormwater runoff from roads and residences. Bank erosion, which may contain historical contamination, is also a potential source. Diverting direct road runoff and closing the existing outfalls should result in a significant decrease in these contaminants. The Service recommends the removal of urban trash, such as car batteries which are a common source of heavy metals. Addressing the stream stability issues should mitigate contaminant contributions from the stream banks.

The D.C. government has large-scale plans for replacement and/or retrofitting existing sewer lines and combined sewer outfalls. As the Watts Branch design phase progresses, the Service and D.C. will need to coordinate both stream rehabilitation recommendations and sewer replacement/retrofit activities to capitalize on similar objective and to repair and avoid fish passage obstructions.

The primary source of sediment is from instream erosion. Restoration techniques (*e.g.*, vanes, and cross vanes) can divert stream flows away from the stream banks and reduce bank stresses. Addressing the stream stability issues through the use of these restoration techniques will reduce sediment contributions from within the stream. In addition, the riparian buffer establishment could function as a filter to remove sediment in overland sheet flow. Riparian buffer establishment will also help address high stream temperatures.

B. Stream Stability

The F4 Rosgen stream type has a poor recovery potential on its own, even if the cause of instability is corrected (Rosgen 1996). To return the stream to a stable condition, the Service recommends a stream restoration plan which establishes a stable stream dimension, planform and longitudinal profile for the stream. A proactive approach will also minimize further environmental impacts, including excessive sediment loads as the stream attempts to establish a stable state.

There are several alternatives available to either restore, rehabilitate or stabilize the stream, ranging from reestablishing the stream on the historic floodplain to stabilizing the stream in place with associated advantages and disadvantages for each option. Establishing the proper stream dimensions (*e.g.*, entrenchment and width/depth ratio) is critical for all the restoration alternatives and may require removal of the existing stream revetments (*i.e.*, concrete walls, block and brick walls, gabion baskets, etc.), depending on the selected restoration alternative. Wherever possible, the Service will attempt to remove the existing revetments in a cost effective and creative way, such as reusing the materials in the proposed restoration structures.

Advantages and disadvantages of each alternative are described in detail in Rosgen (1997) and a summary is provided in Table 6. Not all alternatives will work for each reach and some reaches may require a combination of alternatives. The restoration alternatives are presented in the order most beneficial to the environment and highest potential for success.

Table 6. Watts Branch Stream Restoration Alternatives (adapted from Rosgen, 1997)

Description	Location	Advantages	Disadvantages
Creation of a Stable, Meandering Stream in the Existing or Historic Floodplain	Lower Reach	1) Establishes a Stable and Dynamic Stream Condition 2) Reduces Bank Height 3) Reduces Stream Erosion	1) May Require Extensive Excavation 2) May Require Filling of the Existing Stream

Table 6. Watts Branch Stream Restoration Alternatives (adapted from Rosgen, 1997)			
Description	**Location**	**Advantages**	**Disadvantages**
Creation of a Stable, Meandering Stream in the Existing or Historic Floodplain	Lower Reach	4) Reduces Sediment 5) Improves Aquatic and Terrestrial Habitats 6) Improves the Natural Aesthetics	3) May Result in Loss of Existing Land Use(s) 4) May Require Grade Control at the Downstream Limit of the Project to Prevent Head-cutting
Establishment of a Stream and Floodplain within the Existing Degraded Stream	Upper Reach	1) Decreases Bank Heights 2) Decreases Stream Erosion 3) Reduces Land Loss 4) Improves Aquatic Habitats 5) Prevents Wide-scale Flooding of the Adjacent Land	1) Experiences Higher Flow Velocities and Bank Stress Due to the Narrower Floodplain 2) Requires Grading and Stabilization of the Upper Stream Banks to Reduce Erosion During Higher Flows 3) Requires Potential Grade Control at the Downstream Limit of the Project, to Prevent Head-cutting
Establishment of a Stream with an Increased Floodprone Area within the Existing Degraded Stream	Confined Stream Reaches and Road Crossings	1) Reduces Land Needed to Establish a Stable Stream 2) Developments next to the Stream Does Not Need to Be Relocated 3) Improves Aquatic Habitat	1) Increases in Material Costs 2) Limits the Creation of a Diverse Aquatic Habitat
Stabilization of the Stream	Confined Stream Reaches and Road Crossings	1) Reduces Excavation Quantities 2) Reduces Land Requirements	1) Increases Material Costs 2) Increases Potential for Failure Because of Excessive Shear Stress and Velocities 3) Limits Aquatic Habitat Depending on Nature of Stabilization Method

1. Stream Creation within the Existing or Historic Floodplain

This alternative creates a stable, meandering stream in the existing or historic floodplain. This alternative establishes a stable and self-maintaining stream with diverse aquatic habitat. This alternative may require excavation for the new stream and filling of the existing stream.

2. Establishment of a Stream and Floodplain within the Existing Stream

This alternative establishes a new stream dimension, pattern, and longitudinal profile within the existing degraded stream. Excavation of the existing degraded stream may be required to create the proper meander pattern. The floodplain is either created at the existing grade or the elevation of the stream bed is raised to allow access to an abandoned floodplain. Although the floodplain is narrower than in the previous alternative, the presence of a floodplain still attenuates flow velocities and bank and bed shear stresses during higher flows. This alternative also relies more on bank vegetation to stabilize the stream but may require additional bank stabilization methods. This alternative has a lower success rate than the first alternative and may require some maintenance.

3. Establishment of a Stream with an Increased Floodprone Area within the Existing Stream

This alternative stabilizes the stream within the existing degraded stream. While this option does not require the creation or establishment of a floodplain, it does require the creation of a floodprone area for energy dissipation. The new stream dimensions will decrease the width/depth ratio and increase the entrenchment of the stream. This alternative relies more on grade control structures to stabilize the stream and dissipate the energy of the stream than either of the previous alternatives. This option reduces land required to establish a stable stream and reduces the need to relocate adjacent land uses encroaching on the floodplain. Additional material costs are required and this alternative does not create a diverse aquatic habitat. This alternative has a lower success rate than the first alternative and may require some maintenance.

4. Stream Stabilization

This alternative stabilizes the stream in its present position. This alternative relies on extensive physical stabilization techniques (*e.g.*, imbricated rip-rap, grade control structures). Currently, the Service is not proposing this alternative because there are typically high material and construction costs, a high risk for failure due to the excessive bank stresses and flow velocities, and it does little to improve aquatic habitat or aesthetics.

C. Stormwater Outfalls and Utility Lines

Closure of all stormwater outfalls/pipes which discharge into Watts Branch would be the most beneficial to the restoration of the stream. However, the DOH has requested that the outfalls be addressed on a case by case basis. The Service will likely recommend closing larger outfalls/pipes and outfalls/pipes which are discharging sewage and potential industrial wastewater. Another alternative is retrofitting the outfalls/pipes to attenuate excessive stormwater flows; however, this will not address the sewage issue. In addition, the retrofit designs should incorporate a reorientation and lowering of the outfall opening to minimize stream erosion. The Service may recommend grade control structures to create pools at the outfall/pipe opening to further dissipate stormwater flows.

The Service will require the location of all utility lines adjacent to Watts Branch, including sewer lines. During the restoration design phase, the Service will identify any utility lines which will impact the restoration and may recommend realignment of those utilities. If realignment of the utility is not possible, the Service will attempt to develop the restoration design around the utility line. Adjacent utility lines frequently prevent the stream from achieving its proper planform that the stream uses to dissipate energy. In these situations, it may be necessary to use additional restoration structures to dissipate the energy along the stream bed.

D. Aquatic Habitat

Addressing the water quality and stream stability problems will resolve many of the aquatic habitat concerns, with the possible exception of instream cover and fish passage. Many of the restoration structures (*e.g.*, cross-vanes and J-vanes) provide instream cover by design. However, the Service may recommend incorporating additional instream cover alternatives. The riparian planting plan will provide a source for large woody debris and overhead cover along the stream bank.

A major obstacle to fish passage is the concrete box culvert in Reach WB-07 (Figure 6). Culvert removal and stream restoration are the most beneficial alternative for Watts Branch. However, the Service recognizes that culvert removal may exceed the financial resources of this project and will investigate other fish passage alternatives for this culvert. Restoration structures (*e.g.*, cross-vanes and step-pools) may resolve fish passage obstructions from utility crossings.

E. Riparian Buffer

Although portions of the riparian buffer have a low density and/or diversity, the most significant problems are in reaches where the buffer cannot provide proper bank stability and the overall narrow width of the buffer. The riparian planting plan is an important component for the restoration of Watts Branch. In areas of high stream bank heights and entrenchment, the Service may recommend modification of the stream banks to allow the riparian buffer to help stabilize the stream banks. The Service also recommends maximizing the width of the riparian buffer and planting native riparian vegetation.

The Service is aware of the riparian reforestation planned this fall by Parks and People. In order to make the best use of resources, the Service will work closely with DOH and/or Parks and People to coordinate the reforestation effort. It may be necessary to delay the reforestation until after the completion of the stream restoration design, because of the preliminary design stage and the current drought. The Service recommends over-wintering the existing tree stock for use in restoration efforts next Spring/Summer.

VIII. REACH RESTORATION RECOMMENDATIONS

This section provides reach-specific restoration recommendations and typical restoration solutions for only the highest priority outfalls and sub-sewersheds. During the design phase the Service will review contributions from all outfalls and sub-sewersheds for potential modification.

A. Upper Reach of Watts Branch

1. Reaches WB-01, WB-02, WB-03, WB-05, WB-06, WB-08 and WB-09

The two most likely restoration alternatives for these reaches are: 1) establishing a stream and floodplain within the existing stream; or 2) establishing a stream with an increased floodprone area within the existing stream. Because of encroachment and confinement from adjacent land uses, the feasibility of creating a stable, meandering stream in the existing or historic floodplain is low.

The first alternative requires restoring a proper channel dimension, meander pattern, and longitudinal profile within the existing stream channel. This may require increasing or decreasing the width/depth ratio and sloping banks to restore the floodplain area. Where the stream is overly wide, a bench can be constructed by either placing fill material in the active stream or excavation of a stream channel. Increasing the floodprone area reduces the stream entrenchment. The floodprone area can be increased by reducing the slope of the stream bank above bankfull, moving the bank landward, or a combination of the two techniques. Typically, this alternative requires creating a proper pattern geometry. The preliminary average design beltwidth is 160 feet. Again, due to stream confinement by existing land uses, creating a proper geometry may not be possible at all locations and wherever possible, the Service will maximize the beltwidth. The creation of a meander pattern may require excavation of the existing stream banks or removal of existing revetments. These reaches possess approximately 4,879 linear feet of stream stabilization consisting of gabions, rip-rap, imbricated rip-rap, stone walls, and concrete walls. The Service will attempt to remove the existing revetments in a cost effective and creative way, such as reusing the materials in the proposed restoration structures (*e.g.*, cross-vanes and J-vanes). If the proper meander pattern cannot be created, the Service will likely propose additional restoration structures to assist in stream stability and habitat creation. The additional restoration structures will help attenuate some of the stream power by dissipating the energy in the stream bed.

The second alternative requires creating a stream with a proper width/depth ratio and increasing the floodprone area. Although certain areas can accommodate the preliminary design beltwidth (*i.e.*, 160 feet), there are several factors which may limit the possibility of restoring a proper meander pattern. These limiting factors include: 1) confinement from utilities, property boundaries, or specific land use designations, 2) confinement from roads and road crossings, and 3) excessive excavation requirements (*e.g.*, 20-foot stream banks). Because creating a proper meander pattern is not feasible, this alternative relies on restoration structures to provide stream stability and attenuate stream power. The construction techniques used to create the stream and enlarge the floodprone area are similar to the techniques described in the first alternative.

Encroachment onto the stream has resulted in some existing land uses being undermined by active bank erosion. Because relocating residential structures may be beyond the scope of this project, realignment of stream may be necessary to preserve existing land uses. Several residential yards located in Reach WB-02 are losing property from active bank erosion. A section of Grant Street located in Reach 9 is undermined by active bank erosion and bank failure. If realignment is not possible, the Service will likely recommend additional stabilization structures to ensure stream stability and protection of the land uses.

The Service has identified six exposed utility lines in these reaches. These utility lines cause a variety of problems and potential restoration concerns for the stream, including obstructions to fish passage and stream confinement. The Service will likely propose realignment of these utilities. If realignment of the utility is not possible, the Service will attempt to develop a design around the utility line, including the use of structures (*e.g.*, step-pools) to provide fish passage over the obstacle.

Based on identified stream impacts and stormwater outfall size, the Service identified eleven outfalls as highest priority for closure or retrofit (Figure 8). The Service identified four sub-sewersheds as highest priority for stormwater source control, primarily because of the sub-sewersheds size (Figure 9). During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for these outfalls, and source control in these sub-sewersheds.

2. Reaches WB-04, WB-10, and WB-11

The two most likely restoration alternatives for these reaches are: 1) establishing a stream and floodplain within the existing stream; or 2) establishing a stream with an increased floodprone area within the existing stream. Although these reaches are less confined, it may not be possible to create of a stable, meandering stream in the existing or historic floodplain, because of flooding concerns.

The conditions for the first alternative are similar to those discussed above in Reaches WB-01, WB-02, WB-03, etc., except for the possible removal of the existing contiguous revetments. Reach WB-04 is significantly impacted by concrete retaining walls along both stream banks. Reaches WB-10 and WB-11 are significantly impacted by contiguous stone retaining walls, typically along one side of the stream. These reaches have approximately 2,172 linear feet of stream stabilization consisting of stone and concrete walls. The Service will attempt to remove the existing revetments in a cost effective and creative way, such as reusing the materials in the proposed restoration structures.

If there are conditions which confine the stream, the Service may recommend the second alternative. The conditions for this alternative are similar to those discussed above in Reaches WB-01, WB-02, WB-03, etc.

Based on identified stream impacts and stormwater outfall size, the Service identified three outfalls in Reaches WB-10 and WB-11 as highest priority for closure or retrofit (Figure 8). No sub-sewersheds have been identified by the Service as highest priority for stormwater source control in these reaches (Figure 9). During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for these outfalls.

3. Reach WB-07

This reach is enclosed in two large concrete box culverts. Removal of the culvert may be beyond the financial resources of this project because of its size, length, and existing building and infrastructures located above the culvert. Although removal of the culvert would be most beneficial to the restoration of the stream, the Service will investigate other fish passage alternatives.

Based on identified stream impacts and stormwater outfall size, the Service identified three outfalls as highest priority for closure or retrofit (Figure 8). The Service identified two sub-sewersheds as highest priority for stormwater source control in these reaches (Figure 9). During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for these outfalls, and source control in these sub-sewersheds.

4. Reach WB-12

The most likely restoration alternative is establishing a stream with an increased floodprone area within the existing stream. This reach is significantly confined by roads (*i.e.*, Anacostia Freeway, Kenilworth Avenue, and Minnesota Avenue) and railroad infrastructures. As a result, it may not be possible to create a stable, meandering stream in the existing or historic floodplain.

Approximately 400 linear feet of stream, along both banks, consists of concrete walls associated with the infrastructures. This section of the reach has an available beltwidth of only 50 feet. This reach also contains 270 linear feet of brick-lined channel. For the brick-lined channel, the Service will recommend removal of the brick and returning the stream to its natural substrate. This section is less confined and wherever possible, the Service will likely maximize the meander pattern.

The success of planted vegetation in this area may be compromised by the lack of available soil nutrients and sunlight, because of the road and railroad infrastructures. Soil amendments will likely be required, and additional stabilization structures may be required in low light areas to establish long term bank stability.

Based on identified stream impacts and stormwater outfall size, four outfalls have been identified as highest priority for closure or retrofit (Figure 8). The Service identified two sub-sewersheds as highest priority for stormwater source control in these reaches, because of the existing industrial land uses (Figure 9). During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for these outfalls, and source control in these sub-sewersheds.

B. Lower Reach of Watts Branch (Reaches WB-13, WB-14, WB-15, and WB-16)

Because of the available beltwidth, the most likely restoration alternative for these reaches is creation of a stable, meandering stream in the existing or historic floodplain. These reaches have available beltwidths ranging from 50 to 1,050 feet, with an average beltwidth of 660 feet. The narrow beltwidth is associated with road infrastructures and accounts for 200 feet.

One of the benefits of this alternative is the proximity of the existing water table to the stream.

The raised water table and the extensive proposed floodplain provides an excellent opportunity for wetland creation. Because of the recreational resources (*i.e.*, play ground, and athletics fields) located in proximity to the stream, the Service will work with D.C. and NPS to identify priority recreational resources for preservation. The Service will likely recommend additional investigation to determine the potential consequences of stream realignment on the closed landfill.

If there are conditions which confine the stream, the Service may recommend establishing a stream and floodplain within the existing stream. The conditions for this alternative are similar to those discussed above in Reaches WB-01, WB-02, WB-03, etc.

The Service has identified one exposed utility line in Reach WB-13. Conditions and potential solutions to address the concerns associated with the utility are similar to those discussed above in Reaches WB-01, WB-02, WB-03, etc.

Based on identified stream impacts and stormwater outfall size, the Service identified three outfalls as highest priority for closure or retrofit (Figure 8). The Service identified no as highest priority for stormwater source control in these reaches (Figure 9). During the design phase, the Service and DOH will determine the feasibility of closure or retrofit for these outfalls.

IX. PRELIMINARY DESIGN AND CONSTRUCTION COSTS

There are four phases associated with restoration design: 1) Development of restoration design criteria, 2) Development of 30% complete designs, 3) Development of 60% complete designs, and 4) Development of 90% (final) designs and specifications.

The first phase (*i.e.*, Development of Design Criteria) is based on Rosgen Level I, II, and III data collected during the stream assessment and reference reach data. However, the Service was unable to identify an appropriate stable reference reach during the stream assessment phase. The Service concentrated the reference reach search within the D.C. and P.G. County watersheds within the vicinity of Watts Branch. The Service, as part of the subsequent design Scope of Work, will broaden the reference reach search to watersheds outside D.C. and P.G. County. If a reference reach is identified and surveyed, the Service will develop dimensionless ratios, based on bankfull dimensions, from the reference reach and apply to the Watts Branch restoration desgin. The design criteria developed from the dimensionless ratios include, but are not limited to, bankfull channel dimensions, radius of curvature, belt width, meander length, and riffle-pool spacing. If the Service cannot find a reference reach, the Service will use, if available, dimensionless reference reach ratios developed by Wildland Hydrology as a basis for the restoration design.

The remaining three phases of design involve the development of actual restoration plans. The conceptual (30%) Restoration Design will include a conceptual design plan form with location of the stream and instream structures. The plan will include areas requiring riparian buffers and plots of typical stream cross-section(s) and longitudinal profile(s). The preliminary (60%) Restoration Design will include detailed stream cross-section(s) and longitudinal profile(s) and details of restoration techniques. The final (90%) Restoration Design will include specifications for all materials used, planting plan and plant specifications, construction sequence, and stakeout plan.

The Service will conduct a feasibility analysis of potential restoration solutions throughout the design phase process. The Service has developed a variety of potential stream restoration, outfall, and source control solutions in this report and will investigate feasibility and costs during the design phase for each site.

The Service has developed preliminary restoration construction costs which are presented in Table 7. Costs are based on the magnitude of instability problems and complexity of potential restoration solutions. The Service derived costs for each reach based on total linear feet of each stream reach. The Service will refine the restoration costs at each phase of design as details of restoration solutions and their locations are finalized. Design costs typically range from 15% to 25% of the construction costs depending upon the magnitude and complexity of problems and constraints existing at the restoration site.

The costs presented in Table 7 differ from the preliminary cost estimates previously provided for several reasons. First, the Service's previous cost estimate did not include restoration cost for Reaches WB-01 and WB-07. The Service determined, based upon completion of the data analyses, that Reach WB-01 requires further restoration. And the Service did not have the information needed to develop costs for fish passage at Reach WB-07 at the time of the original cost estimate. Second, the Service was able to develop additional restoration alternatives not considered in the previous cost estimate. Again, this was based upon the completion of data analyses. Finally, the Service refined the original rough estimates of length, resulting in an increase of approximately 3,200 linear feet.

Table 7. Watts Branch Restoration Construction Cost Estimates

Reach		**Cost**	**Reach**		**Cost**
Identification	**Length (ft)**		**Identification**	**Length (ft)**	
WB-01	2,717	$400,000.00	WB-11	965	$195,000.00
WB-02	779	$115,000.00	WB-10	741	$55,000.00
WB-03	905	$90,000.00	WB-11	965	$195,000.00

Table 7. Watts Branch Restoration Construction Cost Estimates					
Reach		Cost	Reach		Cost
Identification	Length (ft)		Identification	Length (ft)	
WB-04	401	$80,000.00	WB-12	941	$190,000.00
WB-05	241	$30,000.00	WB-13	2,588	$195,000.00
WB-06	884	$135,000.00			$515,000.00
		$175,000.00	WB-14	1,082	$80,000.00
WB-07	1,343	$65,000.00			$215,000.00
WB-08	499	$75,000.00	WB-15	665	$50,000.00
		$100,000.00			$135,000.00
WB-09	1,343	$200,000.00	WB-16	785	$60,000.00
		$270,000.00			$160,000.00
WB-10	741	$55,000.00			
TOTAL LENGTH (ft)			TOTAL COST RANGE		
18,585			$1,950,000.00		
			$2,725,000.00		

Note: 1) Total stream length is 16,879. Reach WB-07 is not included because restoration is not recommended for this reach.
2) Some reaches have two cost estimates because there are two distinct restoration alternatives for these reaches.

X. ADDITIONAL RECOMMENDATIONS

A. Assess and Restore P.G. County Portion of Watts Branch

The Service also recommends the assessment and restoration of the P.G. County portion of Watts Branch. Assessment and restoration of the entire stream is important for ensuring the perpetual success of the D.C. restoration, its objectives, and the maximizing the benefits to the environment.

Approximately 9,000 linear feet of Watt's Branch is located in P.G. County. The Service identified two tributaries to Watts Branch. One tributary joins Watts Branch within the D.C. boundary, approximately 3,000 linear feet from the D.C. boundary. Approximately 500 linear feet of stream is exposed, with the remaining portion in D.C. and P.G. County piped. The other tributary enters Watts Branch in P.G. County, approximately 2,000 linear feet from the D.C. boundary. The headwaters of the tributary appear to be piped, with the remaining portion of the tributary confined in a concrete stream for 1,500 linear feet. In general, the stream and its tributary are impacted by some of the same stream conditions found in the D.C., including channelization, entrenchment, and varying degrees of erosion. A unique situation found in the P.G. County is two instream stormwater management ponds.

B. Biological and Chemical Assessments

The Service recommends that assessments of invertebrate and fish communities be conducted prior to restoration at selected locations in the study reaches (main stem and tributaries) to provide baseline information about the health of stream biota. Then post construction assessments should be conducted to document success of restoration objectives. The assessments should be performed in accordance with the Maryland Biological Stream Survey (MBSS) protocol. Biological surveys in adjoining watersheds have been conducted by the State of Maryland (1994 and 2001). Use of the same protocol will ensure greater comparability among data sets. Assessment should include sampling and analysis of invertebrate and fish communities, evaluation of habitat characteristics, and water quality measurements.

Unlike the Oxon Run scope of work, this recommendation was not in the original scope of work because we thought data was available. However, the available data will not allow us to document biological and/or chemical improvement in response to stream restoration which important for validation our approach to restoring the Watts Branch watershed.

C. Bankfull Discharge Validation

The Service recommends the installation of crest gages and staff plates to assist in the validation of the bankfull determination. During a storm event, the crest gages will allow the Service to determine stream stage, slope, and discharge.

D. Expand Project Objectives

The Service recommends expanding the project objects to include park improvements, wetland creation, public education, and public outreach. Park improvements include aesthetic gardens, bayscaping, and picnic areas. The benefits of wetland creation include groundwater recharge, habitat, and habitat diversity. Public education and outreach opportunities includes providing educational signs along Watts Branch, developing an environmental curriculum with local schools, and involving the public in the restoration of Watts Branch (*e.g.*, riparian and garden plantings).

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